

## The Value of Functional Echocardiography in The Management of Mechanically Ventilated Neonates

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### Abstract

**Background:** Functional echocardiography (fECHO) for the neonates is a targeted bedside cardiovascular ultrasound that aiming to clinical evaluation and management of the current neonatal hemodynamic changes.

**Objective:** This prospective follow up study aimed at assessment of the hemodynamic changes in mechanically ventilated neonates, determination of the correlation between ventilation settings and fECHO.

**Methods:** Fifty mechanically ventilated neonates due to non- congenital respiratory problems underwent fECHO after 24 hours of mechanical ventilation. Thirty neonates continued on mechanical ventilation and were available to 48 hours fECHO follow up.

**Results:** A 24 hours fECHO examination showed; highly significant negative correlation between the right ventricular output (RVO) and the peak inspiratory pressure (PIP)& mean airway pressure (MAP) (P value< 0.01) and significant negative correlation with positive end expiratory pressure (PEEP) (P value< 0.05). A significant negative correlation between the left ventricular output (LVO) and the MAP (P value< 0.05). A highly significant negative correlation between superior vena cava flow (SVC) flow and PIP& MAP (P value< 0.01), while no significant correlations found at 48 hours fECHO examination (P value >0.05). A 24 hours fECHO examination showed 14 patients had significant patent ductus arteriosus (PDA). There was highly significant increase (P value< 0.01) in PDA diameter, left atrial/ aortic ratio (LA/AO ratio), LVO/SVC ratio, left mean pulmonary artery (LPA), significant increase (P value< 0.05) in LVO, and highly significant decrease (P value< 0.01) in SVC flow of significant PDA patients more than non- significant PDA or closed patients.

**Conclusion:** fECHO is an extension of the bedside clinical assessment for neonatal hemodynamic changes, it assisted in many decision taking such as closure of significant PDA, surfactant replacement therapy, increasing total fluid intake, management of pulmonary hypertension.

**Keywords:** fECHO in neonates, PDA with fECHO, mechanical ventilation.

### قيمة الموجات فوق الصوتية الوظيفية للقلب في علاج الأطفال حديثي الولادة على جهاز التنفس الصناعي

**الخلفية:** تعتبر الموجات الصوتية الوظيفية الموجة للقلب نوع من أنواع الأشعة التشخيصية المستخدمة لتقييم المريض بالسرير والتي تهدف إلى تحسين التقييم التشخيصي والعلاجي للمريض حيث يتم تعليم وتدريب الطبيب المعالج للقيام بها دون الحاجة إلى طبيب أشعة متخصص.

**الهدف:** هدف البحث إلى تقييم تغيرات الدم الديناميكية للرضع حديثي الولادة المعتمدين على جهاز التنفس الصناعي. بالإضافة إلى إيضاح العلاقة بين ضوابط ومقاييس جهاز التنفس الصناعي ووظائف القلب.

**خطة البحث:** شمل البحث دراسة وصفية تتبعية على ٥٠ ولدا حديثي الولادة ممن يعانون من مشاكل تنفسية بالجهاز التنفسي والتي ليست بسبب عيوب تكوينية إلى فحص بالموجات الصوتية الوظيفية للقلب بعد ٢٤ ساعة من وضعهم على جهاز التنفس الصناعي. وقد اتاح متابعة ٣٠ ولدا فقط استمروا على جهاز التنفس الصناعي بعد ٤٨ ساعة.

**النتائج:** قد أظهر فحص الموجات الصوتية الوظيفية للقلب بعد ٢٤ ساعة وجود علاقة عكسية ذات دلالة احصائية ما بين ضوابط جهاز التنفس الصناعي MAP, PIP, PEEP ودم المدفوع من البطين الايمن. وعلاقة عكسية ذات دلالة احصائية بين MAP ودم المدفوع من البطين الايسر. وعلاقة عكسية ذات دلالة احصائية ما بين PIP, PEEP ومعدل سريان الدم بالوريد الأجوف العلوي. بينما لا توجد أي علاقات ذات دلالات احصائية في فحص الموجات الصوتية الوظيفية للقلب بعد ٤٨ ساعة. وقد بين فحص الموجات الصوتية الوظيفية للقلب بعد ٢٤ ساعة وجود ١٤ مريض يعانون من وجود وصله شريانية مفتوحة حيث يعانون من زيادة ذات دلالة احصائية في قطر الوصلة الشريانية، الدم المدفوع من البطين الايسر، ضغط الشريان الرئوي الايسر، النسبة بين حجم الاذين الايسر والشريان الأورطي، النسبة بين الدم المدفوع من البطين الايسر ومعدل سريان الدم بالوريد الاجوف العلوي. وانخفاض ذات دلالة احصائية في معدل سريان الدم بالوريد الاجوف العلوي. بينما هناك زيادة في الضغط الانقباضي للبطين الايمن ولكنها ليست ملحوظة. وذلك عند مقارنتهم بمجموعه المرضى ذو الوصلة الشريانية المغلقة او غير مؤثره.

**الاستنتاج:** تعتبر الموجات الصوتية الوظيفية للقلب استكمال للتقييم الأكلينيكي لحديثي الولادة والتغيرات الديناميكية لسريان الدم.

**الكلمات الداله:** الموجات الصوتية الوظيفية للقلب لحديثي الولادة، الوصلة الشريانية المفتوحة مع الموجات الصوتية الوظيفية للقلب، التنفس الصناعي.

## Introduction:

Functional echocardiography (fECHO) is referring to usage of targeted cardiovascular ultrasound serving the clinical and medical intervention. In the intensive care units, non- ultrasound physicians are taught and trained on ECHO machine to provide the needed medical ultrasound information (El- Khuffash and McNamara, 2011).

This approach does not aim to replace the ultrasound and cardiology specialists' job and function. It is designed to support clinical decision and provide more information to understand the physiological processes, pathological conditions, and monitor the treatment response. This is an approach that supports the clinical examination with bedside radiological assessment (Beaulieu, 2007).

Functional echocardiography is delivered from the need of continuous monitoring of the hemodynamic state of critically sick patients. In many NICUs, it is not feasible to have a cardiologist available day and night to provide urgent help. Additionally, detailed and specialty secretes and tricks of neonatology are not always provided by the pediatric cardiologist (de Waal and Kluckow, 2010).

Newborn especially preterm is considered the high risk group for mortality and morbidity. Majority of their health issues are respiratory problems, so the lung is assumed as merely one component of the cardiorespiratory system (Wyllie, 2015).

Positive pressure ventilation induces changes in intrapleural or intrathoracic pressure and lung volume, which can independently affect the key determinants of cardiovascular performance (Shekerdemian and Bohn, 1999).

Hemodynamic effects of positive pressure ventilation includes the following: a decrease in venous return of the right ventricle and left ventricle, increases in the ventricles interaction, an increase in pulmonary venous resistance, an increase in central venous pressure and a decrease in left ventricle after load. This leads to a drop in cardiac output and systolic blood pressure (Soni and Williams, 2008).

## Aim of the study:

The current study was carried out evaluate the importance of functional echocardiography in the assessment the hemodynamic changes in mechanically ventilated neonates, and to determine the correlation between ventilation settings and functional echocardiography.

## Design and Methods:

This prospective follow up study was conducted on fifty mechanically ventilated neonates on synchronized intermittent mechanical ventilation (SIMV) mode at NICU of Obstetrics and Gynecology Hospital of Ain Shams University. The study included both preterms and full terms suffering from respiratory problems and admitted at NICU. While it excluded neonates with congenital malformations, and neonates with congenital structural heart diseases (other than patent ductus arteriosus (PDA) or foramen oval).

A written informed consents were obtained from the parents of the enrolled neonates after explanation the goals and aims of our study. All

patients were subjected to; full History taking, thorough clinical examination, ventilation settings recording (mean airway pressure (MAP), fractional inspired oxygen concentration (FIO<sub>2</sub>), positive end expiratory pressure (PEEP), peak inspiratory pressure (PIP), respiratory rate (RR), inspiration time (TI), expiration time (TE), flow, and oxygen saturation, oxygenation index (O<sub>2</sub> index)), lab investigations and chest X- ray.

All subjects underwent fECHO examination after 24 hours of mechanical ventilation, and then followed up after 48 hours of mechanical ventilation. fECHO parameters included; right ventricular output (RVO), left ventricular output (LVO), superior vena cava blood flow (SVC flow), patent ductus arteriosus (PDA), and patent foramen ovale (PFO), right ventricular systolic pressure (RVSP), left pulmonary artery pressure (LPA), left atrium to aorta ratio (LA/ AO ratio), ejection fraction (EF%) and shortening fraction (SF%).

## Statistical Methods:

The collected data were coded, tabulated, and statistically analyzed using SPSS program (statistical package for social science) version 18.

Descriptive statistics were done for numerical parametric data as inferential analyses were done for quantitative variables using independent t- test in cases of two independent groups with parametric data and paired t- test in cases of two dependent groups with parametric data, while correlations were done using Personal Correlation for numerical parametric data. The level of significance was taken at P value< 0.05 is significant, otherwise is non- significant. The P value is statistical measure for the probability that the results observed in a study could have occurred by chance.

## Results:

The study enrolled 50 neonates, they were 19 females (38%) and 31 males (62%). Nine cases were full terms (18%) and the rest 41 (82%) were preterms. The mean gestational age determined by Ballard's score was 32.8± 3.4 weeks, while the mean birth weight was 1.69± 0.72 Kg in the study group. The causes of respiratory distress were; RDS (78%), pneumonia (16%), and transient tachypnea of the newborn (2%). About 6% of patients had combined causes of respiratory distress diagnoses.

All patients were screened for congenital heart disease before they underwent fECHO examination after 24 hours of mechanical ventilation. Only 30 neonates of them underwent fECHO examination after 48 hours of mechanical ventilation because 10 neonates died and 10 neonates improved and shifted from mechanical ventilation.

On studying the correlation between ventricular function and ventilation parameters at 24 hours (50 patients), it was found highly significant and significant negative correlations between MAP and RVO (P value< 0.01)& LVO (P value< 0.05) respectively. Also, RVO was significantly negatively correlated with PIP& PEEP (P value< 0.05) while no significant correlation was detected between LVO and PIP& PEEP (P value> 0.05) (Table (2)). After 48 hours of ventilation (30 patients) RVO and LVO showed no significant correlations with MAP, PIP& PEEP (P value> 0.05) (Table (3)).

The current study showed that fECHO done 24 hours post ventilation (50 patients) revealed significant negative correlation between SVC flow and PIP& MAP (P value< 0.05), while not significant with PEEP (P value> 0.05) (Table (2)). On the other hand the fECHO done 48 hours post ventilation (30 patients) showed that no significant correlation was found between SVC flow and ventilator pressure parameters (PIP, PEEP and MAP) (Table (3)).

Our study showed that there is positive significant correlation (P value< 0.05) between RVSP and ventilation settings (PIP, PEEP, MAP and FIO<sub>2</sub> requirements) at 24 hours post ventilation fECHO examination (Table (2)). While at 48 hours post ventilation fECHO examination there was only significant positive correlation (P value< 0.05) between RVSP and MAP& FIO<sub>2</sub> requirements (table (3)).

On comparing between the mean values of 24 hours and 48 hours post ventilation ventricular output (RVO& LVO) of the follow up group (30 patients) (Table (1)), it appeared that no significant difference between them (P value> 0.05). On the other hand mean value of SVC flow of the follow up group (30 patients) at 48 hours post ventilation fECHO (94.07± 17.14 ml/ kg/ min) was significantly increased (P value< 0.05) as compared to 24 hours post ventilation fECHO mean value (83.34± 18.06 ml/ kg/ min) (Table (1)).

Superior vena cava flow assessment at 24 hours post ventilation fECHO revealed that: Three patients out of fifty (6%) had SVC flow< 55 ml/ kg/ min and eight patients out of fifty (16%) had SVC flow> 55- 70 ml/ kg/ min (Figure (1)).

Twenty four hours post ventilation fECHO revealed that 14 patients had significant PDA (Table (4)). On comparing the significant PDA and non- significant (or closed) PDA patients at 24 hours post ventilation fECHO it was found that there was highly significant increase (P value< 0.01) in PDA diameter, LA/AO ratio, LVO/ SVC ratio, LPA, and significant increase in LVO (P value< 0.05), while highly significant decrease (P value< 0.01) in SVC flow of significant PDA patients more than non- significant PDA or closed patients. On the other hand the RVSP was increased but not statistically significant in significant PDA patients (P value> 0.05) (Table (5)).

Table (1) Comparison between 24 hours and 48 hours of mechanical ventilation settings for the followed up group

fECHO	After 24 Hr		After 48 Hr		T- Test	
	Mean	±Sd	Mean	±Sd	t	P- Value
Pda Size (Cm)	0.14	0.03	0.14	0.04	0.420	0.677
Pfo (Cm)	0.28	0.10	0.24	0.10	1.203	0.235
LPA (m/sec.)	0.17	0.07	0.18	0.07	-0.240	0.811
Rvsp (Mmhg)	35.04	11.04	34.93	10.22	0.038	0.970
RVO (ml/kg/min)	206.32	43.79	222.69	48.33	-1.304	0.198
LVO (ml/kg/min)	181.66	43.24	195.57	43.62	-1.177	0.244
SVC (ml/kg/min)	83.34	18.06	94.07	17.14	-2.240	0.029*
Lvo/ Svc	2.22	0.60	2.08	0.41	0.997	0.323
La/Ao	1.07	0.11	1.08	0.11	-0.313	0.755
Ef%	66.22	5.08	65.96	3.42	0.220	0.827
Fs%	33.48	3.60	33.48	2.82	0.000	1.000

(Non- significant if ≥0.05, \*Significant if< 0.05, \*\*Highly significant if< 0.01)

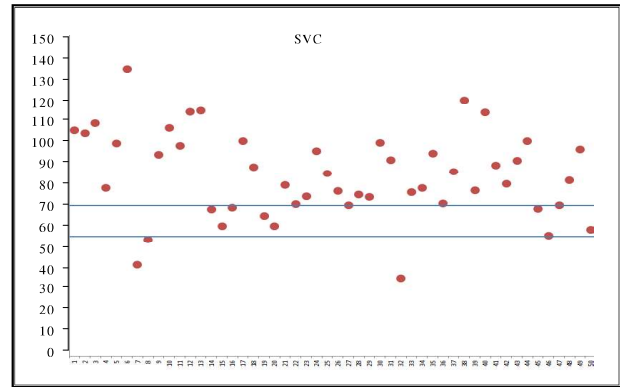


Figure (1) shows the distribution of SVC flow values at 24 hours post ventilation.

Table (2) Correlations between ventilatory settings and fECHO examination at 24 hours of mechanical ventilation

fECHO	RVO	LVO	PFO	PDA	RVSP	SVC	Lvo/ SVC	La/Ao	Ef%	Fs%	
PIP	r	-0.440	-0.142	-0.022	0.280	0.289	-0.423	0.330	-0.022	-0.019	-0.027
	p	0.001**	0.327	0.885	0.072	0.042*	0.002**	0.019*	0.881	0.897	0.855
PEEP	r	-0.333	-0.245	0.173	0.055	0.332	-0.204	0.039	-0.051	-0.013	-0.023
	p	0.018*	0.087	0.245	0.730	0.019*	0.154	0.787	0.726	0.930	0.876
MAP	r	-0.369	-0.283	0.122	0.055	0.396	-0.461	0.248	-0.095	-0.052	-0.060
	p	0.008**	0.046*	0.413	0.731	0.004**	0.001**	0.082	0.510	0.722	0.680
Fio <sub>2</sub> (%)	r	-0.108	0.107	0.056	0.358	0.591	-0.097	0.253	0.240	-0.226	-0.230
	p	0.456	0.460	0.710	0.020	0.001**	0.504	0.076	0.093	0.119	0.112
O <sub>2</sub> Index	r	-0.265	-0.183	0.246	0.212	0.510	-0.213	0.178	0.066	-0.146	-0.162
	p	0.063	0.203	0.096	0.177	0.001**	0.138	0.217	0.651	0.317	0.265
Rate	r	-0.243	-0.312	0.107	-0.033	0.104	-0.330	0.118	-0.066	-0.148	-0.110
	p	0.089	0.027*	0.475	0.833	0.474	0.019*	0.414	0.650	0.311	0.454
TI	r	-0.226	-0.271	0.128	-0.078	0.122	-0.114	-0.075	-0.127	-0.066	-0.031
	p	0.115	0.047*	0.391	0.623	0.398	0.429	0.604	0.381	0.654	0.835
TE	r	0.227	0.350	0.048	0.210	-0.071	0.199	0.055	0.137	0.262	0.236
	p	0.112	0.013*	0.751	0.182	0.624	0.166	0.702	0.344	0.069	0.102
L/E	r	0.258	0.396	0.020	0.207	-0.086	0.208	0.075	0.145	0.255	0.221
	p	0.071	0.004**	0.895	0.187	0.551	0.147	0.604	0.315	0.077	0.126

Non- significant if ≥0.05, \*Significant if< 0.05, \*\*Highly significant if< 0.01

Table (3) Correlations between ventilatory settings and fECHO examination at 48 hours of mechanical ventilation for followed up group:

After 48hr	RVO	LVO	PFO	PDA	RVSP	SVC	Lvo/ SVC	La/Ao	Ef%	Fs%	
PIP	r	0.045	-0.077	0.359	0.045	0.233	0.185	-0.261	-0.208	0.043	0.051
	p	0.835	0.719	0.093	0.856	0.273	0.386	0.219	0.329	0.843	0.815
PEEP	r	-0.016	-0.153	0.500	0.065	0.342	0.026	-0.197	-0.173	0.130	0.128
	p	0.939	0.475	0.015*	0.790	0.102	0.904	0.357	0.419	0.544	0.552
MAP	r	-0.219	-0.328	0.340	0.162	0.506	0.186	-0.511	-0.226	0.194	0.171
	p	0.272	0.095	0.089	0.470	0.007**	0.353	0.006	0.257	0.333	0.394
Fio <sub>2</sub> (%)	r	-0.152	-0.141	0.443	0.235	0.528	0.127	-0.277	-0.066	0.123	0.134
	p	0.450	0.482	0.023*	0.293	0.005**	0.528	0.162	0.744	0.541	0.506
O <sub>2</sub> Index	r	-0.226	-0.292	0.390	0.124	0.416	0.022	-0.347	-0.122	0.204	0.173
	p	0.257	0.140	0.049*	0.582	0.031*	0.912	0.076	0.543	0.308	0.388
Rate	r	-0.104	-0.227	0.448	-0.037	0.347	-0.039	-0.256	-0.113	0.221	0.271
	p	0.628	0.287	0.032	0.882	0.097	0.858	0.227	0.599	0.299	0.199
TI	r	-0.133	-0.177	-0.281	-0.385	0.102	-0.223	-0.008	-0.123	0.219	0.328
	p	0.536	0.409	0.194	0.104	0.635	0.294	0.971	0.568	0.304	0.117
TE	r	0.113	0.196	-0.179	0.282	-0.229	-0.066	0.347	0.118	-0.232	-0.335
	p	0.599	0.358	0.415	0.242	0.281	0.758	0.097	0.582	0.276	0.109
L/E	r	0.103	0.218	-0.143	0.400	-0.211	-0.020	0.321	0.142	-0.290	-0.403
	p	0.631	0.305	0.516	0.090	0.323	0.927	0.126	0.507	0.169	0.051

(Non- significant if ≥0.05, \*Significant if< 0.05, \*\*Highly significant if< 0.01)

Table (4) Percentage Of Patients With Significant PDA 24 Hours Post Ventilator Fecho Examination

PDA Significance	No.	%
Non- significant or closed PDA	36	72
Significant PDA	14	28
Total	50	100

This table shows that 28% of patients had significant PDA during 24 hours post ventilator fECHO examination.

Table (5) Comparison between significant PDA and non- significant (or closed) PDA patients as regards fECHO parameters at 24 hours post ventilation examination

fECHO	Pda Significance				T- Test	
	Non- significant or closed PDA (no. 36)		Significant PDA (No. 14)			
	Mean	±Sd	Mean	±Sd	t	P- Value
RVO(ml/kg/min)	211.70	42.89	204.54	37.49	0.548	0.586
LVO(ml/kg/min)	177.34	35.06	206.33	44.02	- 2.441	0.018*
SVC(ml/kg/min)	90.57	19.21	69.22	11.58	3.878	<0.001**
La/Ao	1.05	0.09	1.20	0.11	- 5.033	<0.001**
Lvo/Svc	2.00	0.48	2.98	0.43	- 6.753	<0.001**
Rvsp (MmHg)	34.69	11.11	38.21	10.81	- 1.013	0.316
Pda Size(Cm)	0.14	0.03	0.20	0.06	- 4.423	<0.001**
LPA (m/sec. )	0.14	0.05	0.31	0.06	- 10.265	<0.001**

Non- significant if ≥ 0.05, \*Significant if < 0.05, \*\*Highly significant if < 0.01

**Discussion:**

Adequacy of neonatal blood flow and hemodynamic circulation is determined by echocardiographic assessment of LVO and RVO (El-Khuffash& Manamara, 2011). The SVC flow has been proposed to be a better ECHO measure of systemic blood flow as it reflects exclusive venous return from the head and upper part of body and is untainted by shunts (Kluckow and Evans, 2000).

Hemodynamic effects of positive pressure ventilation includes the following: a decrease in venous return of the right ventricle and left ventricle, increases in the ventricles interaction, an increase in pulmonary venous resistance, an increase in central venous pressure and a decrease in left ventricle after load. This leads to a drop in cardiac output and systolic blood pressure (Soni and Williams, 2008).

On studying the correlation between ventricular function and ventilation parameters at 24 hours (50 patients), it was found highly significant and significant negative correlations between MAP and RVO& LVO (P value< 0.01)& (P value< 0.05) respectively. Also, RVO significantly negatively correlated with PIP& PEEP (P value< 0.05) while no significant correlation was detected between LVO and PIP& PEEP (P value> 0.05) (Table (2)). That could be explained by the presence of significant PDA.

After 48 hours of ventilation RVO and LVO showed no significant correlations with MAP, PIP& PEEP (P value> 0.05). These findings might be due to decrease of sample size as only the remaining 30 patients on mechanical ventilation who underwent for fellow up fECHO at 48 hours (Table (3)).

The current study showed that fECHO done 24 hours post ventilation (50 patients) revealed significant negative correlation between SVC flow and PIP& MAP (P value< 0.05), while not significant with PEEP (P

value> 0.05) (Table (2)). On the other hand the fECHO done 48 hours post ventilation (30 patients) showed that no significant correlation was found between SVC flow and ventilator pressure parameters (PIP, PEEP and MAP) (Table (3)), which could be explained by increasing the total fluid intake for patients with low SVC flow, treating significant PDA, or decreased sample size in the follow up group.

The key parameter affecting interactions is MAP which directly influences mean intrathoracic pressure. MAP is the difference between PIP and PEEP {MAP= ((PIP- PEEP)× TI/ TI+TE)+ PEEP} (Donn, 2012).

In addition, the mean PEEP used for our cases was 5.09± 0.62 cm H<sub>2</sub>O at 24 hours of ventilation (50 patients) and 5.39± 0.70 cm H<sub>2</sub>O at 48 hours of ventilation (30 patients). These means of PEEP were considered as low as to affect the SVC flow.

Many studies and reviews consider PEEP levels less than 5 cm H<sub>2</sub>O a low PEEP, and PEEP levels more than 5 cm H<sub>2</sub>O a high PEEP. The PEEP cut- off value at 5 cm H<sub>2</sub>O is a common value applied in many neonatal units (De Waal et.al., 2007) and (Bamat et.al., 2012).

Our study showed that there is positive significant correlation (P value< 0.05) between RVSP and ventilation settings (PIP, PEEP, MAP and FIO<sub>2</sub> requirements) at 24 hours post ventilation fECHO examination (Table (2)). While at 48 hours post ventilation fECHO examination there was only significant positive correlation (P value< 0.05) between RVSP and MAP& FIO<sub>2</sub> requirements (Table (3)).

Pulmonary hypertension and RVSP is directly related to pulmonary vascular resistance of the lung and neonatal prematurity (Mertens et.al., 2011). That explains the relation between the RVSP and high ventilation pressures and oxygen requirements.

This study showed that; at 24 hours post ventilation fECHO the mean value of RVO was 209.7± 41.2 ml/ kg/ min and the mean value of LVO was 185.46± 39.56 ml/ kg/ min (50 patients). While at 48 hours post ventilation fECHO the mean value of RVO was 222.69± 48.33 ml/ kg/ min and the mean value of LVO was 195.57± 43.62 ml/ kg/ min (30 patients). On comparing between 24 hours and 48 hours ventricular output (RVO& LVO) for follow up group (30 patients) revealed that no significant difference between them (Table (1)).

Normal values for both right and left ventricular outputs range from 170 to 320 ml/ kg/ min. A cut off value of RVO or LVO is less than 150 ml/ kg min and it is associated with increased morbidity and mortality (De Waal and Kluckow, 2010). The averages of our patients' results are consistent with other many studies done to determine the normal average values of ventricular output (Noori et.al., 2012), (Popat and Kluckow, 2012) and (Lakkundi et.al., 2014).

The current study revealed that at 24 hours post ventilation fECHO the mean of SVC flow was 84.59± 19.82 ml/ kg/ min (50 patients), while at 48 hours post ventilation fECHO it was 94.07±17.14 ml/ kg/ min (30 patients).

Comparison between 24 hours and 48 hours SVC flow for follow up

group (30 patients) revealed the presence of significant increase in the mean of 48 hours SVC flow (table (1)), it was  $83.34 \pm 18.06$  ml/kg/min at 24 hours fECHO examination compared by  $94.07 \pm 17.14$  ml/kg/min at 48 hours fECHO examination, which can be explained by increasing total fluid intake for patients with low SVC flow and presence of PDA significant patients that received medical treatment. The ranges of our patients' results are consistent with (Groves et.al., 2008) and (Lakkundi et.al., 2014). The cut- offs are usually within a range of 40- 55 mL/kg/min and are generally based on the findings of earlier studies (McGovern and Miletin, 2017). However, SVC flow < 50- 55 ml/kg/min has been proven to be associated with poor neurological and developmental outcome (Groves et.al., 2008).

Superior vena cava flow assessment at 24 hours post ventilation fECHO revealed that: Three patients out of fifty (6%) had SVC flow < 55 ml/ kg/ min and eight patients out of fifty (16%) had SVC flow > 55- 70 ml/ kg/ min (figure (1)).

Twenty four hours post ventilation fECHO revealed that 14 patients had significant PDA (table (4)). Assessment of PDA in our study was done by clinical examination and supported by two dimensional and colour Doppler fECHO to reveal the diagnostic criteria of PDA significance (Sehgal and McNamara, 2009).

On comparing the significant PDA and non- significant (or closed) PDA patients at 24 hours post ventilation fECHO it was found that there was highly significant increase ( $P$  value < 0.01) in PDA diameter, LA/ AO ratio, LVO/ SVC ratio, LPA, and significant increase in LVO ( $P$  value < 0.05), while highly significant decrease ( $P$  value < 0.01) in SVC flow of significant PDA patients more than non- significant PDA or closed patients. On the other hand the RVSP was increased but not statistically significant in significant PDA patients ( $P$  value > 0.05) (table (5)).

The hemodynamic significance of PDA is determined by many criteria depending on ductal size, flow pattern and direction of the shunt. Increased left to right shunt leads to reversed diastolic flow in descending aorta, with increased left atrial and left ventricular enlargement. Significant hemodynamic shunt is associated with proportional increase in LVO and decrease in SVC flow (Sehgal and McNamara, 2009).

#### Conclusions:

From the results of this study we conclude that Application of fECHO in NICU is considered as an extension of the bedside clinical assessment. Functional echocardiography has a great importance in assessing cardiac output, PDA significance, RVSP, contractility, vascular filling and SVC flow. More studies are needed to document the correlation between ventilation settings and fECHO parameters.

#### Recommendations:

From the results of this study we recommend that Wide application of fECHO in the NICU with continues training and education of neonatologists performing fECHO. Decision taking and management of sick neonates should be started after targeted fECHO examination. Large cohort studies are needed to reveal the correlations between changes of

different ventilation setting parameters and fECHO findings.

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